No. 3

Boeing 727-200, JY-ADU, accident at Doha International Airport, State of Qatar, on 13 March 1979.
Report No. 1/79, dated 15 December 1979, *released by the State of Qatar.*

SYNOPSIS

The accident was notified by Doha International Airport air traffic services on 13 March 1979.

The Civil Aviation Department carried out an investigation and the following groups were established:

Operations; Engineering; Flight Recorder; Witness;
Meteorological; Air Traffic Services; Airport Fire Service.

The States of Registration and Manufacture were notified of the accident and accredited representatives were appointed to participate in the investigation.

The accident happened at night when the aircraft was executing a missed approach procedure on Runway 34 at Doha International Airport. Following the initiation of the missed approach procedure and on reaching a height of approximately 750 ft above aerodrome level the aircraft encountered a thunderstorm the effects of which exceeded the climb performance of the aircraft and forced it to the ground.

Note.- *Technical Services at Doha International Airport, including Air Traffic* Services, Meteorological Services, Fire and Rescue Services, Motor Transport Services and Airport Electrical and General Maintenance Services, are provided by International Aeradio Limited under contract to the Government of the State of Qatar.

1. FACTUAL INFORMATION

1.1 History of the Flight

The Boeing 727 aircraft registration JY-ADU, using call sign Royal Jordanian 600, was operating a scheduled passenger service from Amman to Doha and Muscat.

With the First Officer as the handling pilot the aircraft left Amman at the scheduled time of 2155 on 13 March 1979 with a total of 64 on board. The first part of the flight was uneventful. As it drew near Doha the aircraft encountered turbulence.

R/T contact was established with Doha at 2308 at a range of 45 miles when the controller passed on the following weather information:

Wind velocity 090°/17 kt, visibility 10 km in thunderstorms, 1/8 CB at 2 500 ft, 3/8 at 3 000 ft, QNH 1008. The controller added that the thunderstorm appeared to be building up over and to the north west of the airfield.

After some R/T exchanges as to which runway was preferable, the pilot requested Runway 16 and was cleared for a visual approach to that runway or for a NDB/VOR approach if visual contact with the airfield was not established. The aircraft reported approaching the overhead position for a NDB/VOR procedure at 2317 and was seen by the controller as it positioned for the outbound leg of the procedure. On the airfield rain was falling quite heavily and the controller informed the aircraft of this. At this stage the NDB tripped and the controller informed the aircraft accordingly adding that, in his opinion, this was in consequence of a lightning strike. At 2322.30 the controller advised that the NDB was back on the air. Lightning was intense and continuous close to the airfield to the north and north-west.

At 2325 the aircraft reported procedure turn complete and was cleared to land. In the course of the approach the following winds and information were passed to the aircraft:

Wind 010°/08 kt-backing; 340°/06 kt; 340°/less than 5 kt with heavy rain; 290°/14 kt.

At 2329 the aircraft reported that it had not seen the runway, and initiated a missed approach, requesting and receiving clearance to make an ILS approach to Runway 34. At 2330 the controller gave the aircraft a wind of 280°/16 kt and at 2331 a wind of 290°/14 kt, a QNH of 1011 mb, and a report of heavy rain. At 2335 the aircraft reported procedure turn complete and field in sight. Landing clearance was given with a wind of 180°/06 kt.

During the next 2 minutes of the final approach the controller reported winds of 150°/13 kt, 150°/15 kt, and 140°/17 kt; he also gave the pilot an "unofficial" report (i.e. not based on an observation by a meteorological observer) that the rain was very heavy and that visibility from the tower was probably less than 1 000 m.

Note.- All times in this report are GMT. Local time is GMT plus 3 hours.

Because of the increasing tail wind component and difficulties in maintaining the glide path both pilots simultaneously decided, before reaching decision height, that a missed approach was necessary and this was initiated at 2337.19 at a height of approximately 300 ft above aerodrome level (a.a.l.). The pilot then requested clearance to Dahran and the controller cleared the aircraft to climb straight ahead to FL 80.

In accordance with Flight Manual procedures "go around" power was applied and established: 25° flap was selected: the undercarriage was raised and the "go around" attitude of 12° established, producing an average rate of climb approaching 1 300 ft/min. The flight data recorder shows that the aircraft climbed to 750 ft a.a.l. with the indicated airspeed (IAS) falling to approximately 140 kt. The aircraft then began to descend at an increasing rate until it struck the ground with a vertical speed of 4 200 ft/min., with the IAS increasing rapidly to approximately 170 kt in the last 5 s. The cockpit voice recorder shows that in the last 11 s before impact the Ground Proximity Warning System (GPWS) gave a continuous aural warning, and that during this period the crew increased power from the "go around" setting to maximum. The aircraft struck the ground on the left-hand edge of the runway, 2 050 m from the threshold with the nose approximately 10° above the horizon and with the left wing 5° down.

The aircraft "bounced" off the first impact and turning left, rolled to the right to an inverted position and then slid, tail first, into the Fire Station garage some 800 m from the first impact point and 270 m from the runway edge. The fuselage broke into three main sections during the process.

The nose and centre sections were destroyed by fire but the tail section remained untouched by fire.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	4	41	
Non-Fatal	9	6	
None	2	2	
Total:	15	49	

The First Officer and the Flight Engineer survived the accident.

1.3 Damage to Aircraft

The aircraft was destroyed by impact and fire.

1.4 Other Damage

Three runway and one taxiway light fittings were broken and a marker board alongside the runway designating the displaced daylight threshold of RW 16 was demolished.

A six-bay garage and store building together with miscellaneous stores and equipment were destroyed by impact and fire.

Windows in the Fire Station and in the Fire Services Watchroom were broken by blast and flying debris.

The front facet of the Fire Station suffered minor impact damage.

One water tanker, one emergency tender, one ambulance and one passenger bus were destroyed. One foam tender suffered considerable fire damage.

1.5 Personnel Information

1.5.1 Flight Crew

The Captain, aged 32, held Airline Transport Pilot Licence No. 371, issued by the Kingdom of Jordan on 18 May 1977. It was valid until 6 July 1979 and was endorsed for pilot-in-command on Boeing 727 aircraft. His last instrument rating and proficiency check was carried out on 5 January 1979. His last medical examination was 15 October 1978, when he was assessed as fit. He had flown a total of 4 606 hours, of which 102 were in command on B 727's. In the thirty days prior to the accident he had flown a total of 50 hours 05 minutes. Immediately prior to the accident he was on standby from 1000 to 2200 on 11 March and had a rest day on 12 March. He was authorized to give First Officer landings and take-offs, in accordance with Company Orders, on 10 March 1979.

The First Officer, aged 38, holds Commercial Pilot Licence No. 418 issued by the Kingdom of Jordan on 26 May 1975. It is valid until 27 March 1979 and is endorsed for Co-pilot on B 727 aircraft. His last instrument rating and proficiency check was on 27 September 1978, and his last medical examination was on 30 January 1979, at which examination he was assessed as fit. He has flown a total of 2 674 hours. In the 30 days prior to the accident he had flown a total of 72 hours 05 minutes. Immediately prior to the accident he had flown 4 hours and 05 minutes on 11 March and had a rest day on 12 March.

The Flight Engineer, aged 24, holds Flight Engineer Licence No. 107 issued by the Kingdom of Jordan on 4 February 1978. It is valid until 16 April 1979 and is endorsed for Flight Engineer on Boeing 727 aircraft. His last proficiency check was on 16 August 1978 and his last medical examination was on 7 March 1978, at which examination he was assessed as fit. He has flown a total of 734 hours. In the 30 days prior to the accident he had flown 39 hours 55 minutes. Immediately prior to the accident he had been on Rest Day on 10 March and standby from 2200 on 11 March to 1000 on 12 March.

1.5.2 Cabin Crew Staff

The cabin crew staff had last taken courses on emergency drills and procedures as follows:

Purser	20/5/78 - 10/6/78
Cabin Attendant	17/7/78 - 30/7/78
Cabin Attendant	13/1/79 - 18/1/79
Cabin Attendant	20/1/79 - 25/1/79
Cabin Attendant	20/1/79 - 25/1/79
Cabin Attendant	16/11/78 - 21/11/78

There were 6 extra crew members on board who were seated throughout the cabin and treated as normal passengers. They had no special safety or survival training, or function within the operational crew framework.

1.6 Aircraft Information

1.6.1 History of Maintenance Synopsis

The aircraft, a Boeing 727-200, was manufactured by the Boeing Aeroplane Co. during 1974 and given the serial number 20886. It was registered in the Kingdom of Jordan by the owner, Royal Jordanian Airline Corporation, on 31 July 1974 and issued with the nationality and registration mark JY-ADU; its number in the Jordanian Aircraft Register was 194. A Certificate of Airworthiness first issued on 10 August 1974 was renewed on 27 September 1978 valid for twelve months.

The aircraft was maintained to an approved maintenance schedule requiring progressive inspection at 200-hour intervals. On 12 March 1979 a maintenance check including schedule items A check, B2 check, C check and Phase F was completed prior to service, at which time the aircraft had accumulated 10 237.30 hours of flight time.

There were no significant defects recorded as outstanding prior to the aircraft's being released for service on the flight during which the accident occurred.

Fuel used in the aircraft was Jet A1.

1.6.2 Weight and Balance

The load sheet for the flight was examined together with the General Declaration Form, passenger and cargo manifests, trim sheet and Captain's load information, and loading instruction form. The load sheet showed a dry operating weight of 47 461 kg, weight of fuel at take-off 19 700 kg, 43 adult passengers and one infant totalling 3 410 kg, baggage 960 kg, cargo 4 654 kg and mail 26 kg. Take-off weight was therefore 76 211 kg; this, minus trip fuel of 9 750 kg, gave a predicted landing weight of 66 461 kg. The maximum authorized landing weight with 30 flap was 72 575 kg and with 40 flap was 64 637 kg. The take-off and zero fuel weight trim settings were within limits.

The Captain's load information did not show a 146 kg consignment of flammable liquid stowed in hold no. 2.

1.7 Meteorological Information

1.7.1 Synoptic Weather Situation: Arabian Gulf

Relatively high surface pressure over Iran, and low level easterly air stream over Saudi Arabia maintained a moist low level easterly air stream over Qatar, and low level convergence over the central and western Gulf produced large CB clouds and thunderstorm activity.

1.7.2 Weather at Doha International Airport

Following relatively clear weather during the morning of 13 March, thunderstorm activity commenced at 1550 at the airport and continued intermittently throughout the afternoon and evening.

The 2257 weather report to ATC indicated thunderstorm activity. Special weather reports at 2329 and 2336 reported thunderstorms which appeared to the meteorological observers to pass directly over the airport. Prior to and at the time the accident occurred, the rainfall was recorded as "Violent". Subsequent analysis of the rain recorder trace at the airport shows that 29 mm of rain fell between 2320 and 2350, which exceeds an equivalent rainfall rate of 50 mm/h. The Captain and First Officer of an aircraft parked on the apron waiting for the weather to clear before taking off both testified that it was the worst storm they had ever seen on the ground - this was at the time JY-ADU had started outbound for an ILS approach on RW 34.

The First Officer aboard JY-ADU, in his evidence, said that at the start of the missed approach off RW 34 there was turbulence and heavy rain.

The airport barogram record shows that the pressure was 1010 mb at 2138 and fell steadily to 1008 mb at 2323. Pressure rose suddenly to 1012 mb between 2323 and 2329 then remained between 1011 and 1012 mb until 2400 and fell slowly thereafter.

From 2317 until 2342 marked changes in wind speed and direction occurred as recorded in paragraph 1.1.

The accident occurred at night.

1.7.3 Weather Information Available to the Flight Crew

The following information regarding Doha weather was given to the aircraft prior to take-off at Amman:

TAF 1800 - 0300, WIND 080/15, VIS 10 KM PLUS
CLOUD 2/8 CU 3000, 3/8 AC 9000
PROBABILITY 30% THUNDERSTORM
TEMPO WIND GUSTING TO 35 KTS
VIS 3000 MTR IN THUNDERSTORM AND
MODERATE OR HEAVY RAIN
METAR 1500Z, WIND 080/14, VIS 10 KM PLUS,
CLOUD 2/8 CU 2500, 1/8 CB 3000, 3/8 AC 9000.
TEMPERATURE 21, DEWPOINT 18
QNH 1010.9

SIGMETS: weather of thunderstorm activity in the area of the FIR Bahrain extending to 23° south, were in operation throughout the period of the flight of the aircraft.

1.8 Aids to Navigation

At 2317 the NDB tripped off and was reset at 2322.

At 2330 the VOR went off the air and was not brought back into service until after the accident, when it was ascertained that the equipment was serviceable but had apparently tripped off due to transients on the power line caused by lightning strikes.

It is believed that the NDB and VOR outages are not relevant to the accident and this is confirmed by the evidence of the First Officer.

The instrument landing system on RW 34 operated normally and the routine flight check on 6 March, as well as a post-accident flight check on 17 March, indicated that the equipment operated within ICAO Cat II tolerances.

1.9 Communications

Two way communications on 118.9 MHz were established and maintained with the aircraft throughout its approach to Doha.

1.10 Aerodrome Information

RW 34/16 has an asphalt surface and is 4 572 m long and 46 m wide. It has green, flush threshold lights and high-intensity bi-directional and low-intensity omnidirectional edge lights. Approach lighting on RW 34 is a variable high-intensity Calvert system, and on RW 16 a variable low-intensity centre line with crossbar system. T-VASIS are installed on both ends of the runway. The runway and its systems were serviceable at the time of the accident.

The meteorological observations are taken from the roof adjacent to the control tower except for the surface wind which is sensed by a 30 ft high anemometer 600 m SSE of the control tower. The control tower and fire station are approximately 3 000 m from the threshold of RW 34 and hence approximately 4 500 m from an aircraft on the glide slope at an altitude of 300 ft.

1.11 Flight Data Recorders

The flight data recorder (FDR), Fairchild type 5424 - 221, serial 2149 and the cockpit voice recorder (CVR), Collins 642 C-1, serial No. 2283 located in the rear portion of the aircraft were recovered undamaged.

The records were transcribed by the UK Accident Investigation Branch and a graphical representation of the FDR data recorded in the final 60 s before impact is annexed to this report.

The US National Transportation Safety Board provided an analysis of the FDR data comparing the rate of climb and acceleration with predicted performance levels of the aeroplane.

Datum corrections were applied in the use of the readouts in the investigation.

1.12 Wreckage

1.12.1 Impact Details; Airframe and Systems Damage

The aircraft first struck the ground on the left edge of RW 34 approximately 2 050 m from the threshold, on a track of 330°M. The first impact occurred with the underside of the rear fuselage at a position on and forward of the aft passenger stairway. The left wing tip and the left wing leading and trailing edge flaps struck at the same time. There was severe damage to the fuselage, aft cabin windows were broken and the rear baggage hold burst open. Both podded engines (nos. 1 and 3) became detached. The first impact damage and ground markings indicated an impact attitude of about 10° nose up and 5° left wing low. The impact configuration was established as landing gear up and locked, inflight and ground spoilers retracted, leading edge slats and flaps extended, trailing edge flaps at or close to the 25° position.

Following the first impact the aircraft "bounced" and reimpacted the ground about 100 m further on, the left wing demolishing the inside marker board for the displaced threshold of RW 16 to the west of the runway. The aircraft then swung to the left and skidded sideways down Taxiway 4. In the area of the intersection of Taxiways 4 and 5 the aircraft rolled to the right to become inverted, causing substantial damage to the right wing and detaching the right wing slats. An impact on the outboard upper surface of the right horizontal stabilizer fractured the horizontal and vertical stabilizers and removed the upper rudder. The major part of the wreckage then slid into the Fire Station garage, the fuselage lying on its right side and travelling rearwards. The fuselage came to rest in three sections; the flight deck and about 14 ft of forward fuselage, a 53 ft section of centre fuselage with wing roots and the remaining tail section.

Fire started at the time the aircraft struck the Fire Station garage. The fire eventually consumed much of the centre fuselage section and inboard mainplanes. The tail section remained untouched by the fire; the flight deck section interior was destroyed.

There was no evidence from examination of the wreckage or its distribution, of airborne structural failure or detachment.

The total disruption due to impact and fire precluded much direct assessment of aircraft system integrity prior to impact; however, evidence from the First Officer and the Flight Engineer coupled with FDR and VCR readouts indicate that systems functioned normally.

There was no evidence of airborne fire or lightning strike.

1.12.2 Engines

Neither the First Officer nor the Flight Engineer noted any engine malfunction prior to impact, and the CVR readout contains no comments by the flight crew about possible power plant failure.

Under the control of the U.S. National Transportation Safety Board the engines were stripped and examined, particularly to determine if performance might have been impaired by water ingestion. The NTSB report concludes that:

> "All of the observed damage in the three engines is indicative of high power operation at ground impact and breakup of the aircraft. Especially noteworthy is the amount of sand deposited throughout the engines. If the engines were at low power, or not operating, when they struck the ground, the sand would not have been found throughout the engine.
>
> "Particularly it would not have been found in such great quantity in the diffuser and combustion sections. The sand could only have collected and packed in those areas and the bleed system during high air flow, and could only have caked on the turbine vanes and blades when they were at operating temperature.
>
> "In addition, the molten metal splatter on the turbine nozzle vanes and turbine blades could only have melted and adhered when those parts were at operating temperature. There is no doubt that this metal came from airframe debris ingested by the engines and from pieces of compressor blade broken out by that debris.

"All the compressor damage noted is foreign object damage, and there is no damage which can be associated with interference between compressor rotor blades and stator vanes. Past experience with the JT8D-17 engine has shown that at extremely high rates of water ingestion under part power conditions, a severe stall may occur which could cause blade-to-vane interference. There is no evidence that such interference occurred in these engines. All the physical indications are that blade clashings did not occur.

"There was nothing found in the engines to indicate that water ingestion affected their operation. All evidence indicates the engines were operating at high power at impact."

1.13 Medical and Pathological Information

There is no suggestion or evidence to suggest that flight crew incapacitation was a factor in the accident.

Of the forty-five persons who died in the accident it was ascertained that the main cause of death in the case of twenty of them was severe burns and the remaining twenty-five suffered fatal impact injuries.

1.14 Fire

1.14.1 Equipment and Organization

At the time of the accident the main strength of the Airfield Fire Service, consisting of five vehicles under the command of the Duty Fire Officer, was at the "bad weather standby" position for RW 34. The position is approximately abeam the touchdown point of RW 34 and is intended to give an improved response time in the event of a landing accident, as well as assisting ATC by allowing the Fire Service to give information about landing aircraft. The remaining fire vehicle in use was in position at the Fire Station which is close to ATC, about 3 000 m from the threshold of RW 34. All equipment in use was serviceable; scales of equipment and manning levels met the requirements of ICAO Aerodrome Category 7, which includes use of the airport by B-727 aircraft.

In general the standard of English spoken in the Fire Service was not high. Routine messages needed to be expressed carefully, and an acknowledgement was not always proof that a message would be correctly understood. On the night of the accident it was noteworthy that both the Watchroom and the Duty Fire Officer followed correct R/T procedures.

The Fire Service Watchroom and all vehicles were equipped with two-way radio equipment which enabled them to communicate on 121.3 MHz, the ground movement frequency (GMF). This was partially ineffective at the time of the accident, although the details were not obvious to users of the frequency. An analysis of transmissions shows that two-way communication existed between ATC and the Fire Service Watchroom, and also between ATC and vehicles at the "bad weather standby" position for RW 34.

However, communications between the Watchroom and the deployed vehicles was intermittent. It was not possible to establish a positive reason for this. It is considered, however, that the impact of the wreckage against the Watchroom, the failure of a radio component in the Watchroom through high levels of lightning activity, the presence of large areas of standing water on the airfield, the screening effect of high-sided vehicles, or a combination of these circumstances may have caused the poor communications.

1.14.2 Fire Fighting Action

The main portion of the wreckage was the fuselage, which slid backwards and sideways, practically upside down, into the Fire Station garage/workshop, breaking into three parts. The larger part, the fuselage centre section, struck vehicle parking bays and the workshop contained cylinders of oxygen and acetylene, together with drums of lubricating oil and other flammable materials.

The impact knocked down several pillars which supported the roof of the vehicle parking bays, bringing rubble and building materials down on the centre section, and also pushed three heavy motor vehicles sideways into each other, demolishing the intervening walls. There was an explosion and an eruption of flame either as the aircraft struck the Fire Station, or very shortly afterwards. The tape recording shows that the Watchroom attendant called "Fire, fire, fire, Watchroom, fire", some seventeen seconds after the aircraft struck the runway. There is some evidence that fire may have begun near the rear end of the broken centre section.

Fuel quickly began to spread around the centre section and to run downhill, away from the Fire Station, clear of the nose and tail sections.

Rescue 6, the vehicle at the Fire Station, closed promptly with the fire in the first few moments after the accident, but the Leading Fireman in charge saw that there were people still alive and in need of assistance. Accordingly he and one of his men went to help, leaving two men to operate the vehicle. The Leading Fireman decided to cease operating the main foam delivery monitor and to use one side hose, so that its lower rate of delivery could sustain protection for the rescue operation over a longer period. Professional opinion is that the Leading Fireman made a sound decision in difficult circumstances. The Duty Fire Officer, with his five vehicles, did not receive positive instructions that there was an accident and that he was needed at the Fire Station until approximately eight minutes after the impact, when the crew of Rescue 6, realizing that they were not being reinforced, called the Duty Fire Officer and his five vehicles to the accident site. It is estimated that a total time of eleven minutes must have elapsed before the Duty Fire Officer and the main force of vehicles were in attendance at the scene of the accident.

The rain was so heavy that, from the control tower, the controller could not visually confirm that the aircraft had crashed into the Fire Station, about 100 m away. The Watchroom had been struck by the wreckage, but the broadcast of "Fire, fire, fire, Watchroom, fire" by the Watchroom attendant was not heard by the Duty Fire Officer. The Duty Fire Officer made attempts to find out what was happening, but to him the situation was confused because he could hear the controller transmitting to the Watchroom, but could not hear the answers. One transmission from the Duty Fire Officer received a hurried reply from the controller who did not wait for an acknowledgement before continuing a conversation with the Watchroom; another request to ATC for information was blocked by other fire vehicles as they started discussing, in their own language, the problems of their vehicles in the heavy rain. A third request, addressed to the Watchroom, produced no answer, either because of the communications problem, or because it was made after the Watchroom was abandoned owing to fumes and heat.

The controller assumed that the Duty Fire Officer had heard the Watchroom cry of "Fire, fire, fire, Watchroom, fire," and, believing that the Watchroom knew more about the situation than he did, took it for granted that the Watchroom would summon the Duty Fire Officer. The orders for controller and Watchroom do not make it clear whose responsibility this was. In fact, the Watchroom attendant took no such action.

When members of the Fire Service conversed in their own language the controller took this as a sign that they were in action at the fire. The person who eventually summoned the Duty Fire Officer at 2436 was a junior fireman, the driver of Rescue 6.

On arrival at the scene of the fire at an estimated time of 2349, the vehicles from the "bad weather standby" position commenced fire control and rescue operations immediately. The extraordinarily heavy rain diluted the foam, and the building materials which were lying on the fuselage centre tended to deflect foam, preventing it from lying on the aircraft itself.

At about 2359, when rescue work was well in hand and the Fire Service thought the fire was under control, there was a loud explosion near the front end of the fuselage centre section. This explosion was sufficiently violent to send metal flying through the air and blew in the remaining windows of the Watchroom. It was accompanied by a renewed outbreak of fire, and was followed by a further explosion at approximately 0014 hrs, less violent in nature. The fire gradually spread to the nose section and was finally brought under control at approximately 0305 hrs. Its is considered that the Fire Service performed commendably once all vehicles had arrived at the site of the fire.

The Doha town fire and ambulance services responded immediately to the '999' call made by ATC as part of the post-accident procedures. The appliances arrived at the accident site some 15 minutes after the call.

1.15 Survival Aspects

Forty-one dead bodies were recovered from the wreckage. Fourteen persons were rescued alive by the Fire Service, four of whom subsequently succumbed to injuries. Nine persons got out of the aircraft by their own efforts.

Of the forty-five deaths, twenty were found to be as a consequence of the effects of fire and twenty-five were due to impact injuries.

The Captain of the aircraft died as a result of impact injuries and was dead when the aircraft came to a stop.

The survivors were recovered in about equal proportions from the front part of the main fuselage and from the tail section. The First Officer was assisted from the flight deck by the Duty Fire Officer in Rescue Vehicle 1. At this time the flight deck was not on fire. Two cabin attendants escaped through a break in the forward fuselage and at least one passenger pushed a window out and escaped through that. Information regarding the evacuation of other persons is of a fragmentary and unco-ordinated nature and of no particular value in assessing the situation.

The aircraft struck the ground initially with a rate of descent of over 4 000 ft/min at a forward speed of over 160 kt. Before coming to rest, the aircraft rolled and turned, striking the ground at least two more times. Some seats became detached from their fastenings and others were severely distorted.

Fire became well established at impact with the Fire Station garage and was immediately attacked by major foam appliance Rescue 6 by monitor-dispensed foam. However, the foam application was, quite correctly, reduced to the use of one side hose to permit the firemen to carry out passenger rescue operations. It has not been possible to assess the effect of this limitation on the progress of the fire.

Rescue Vehicles 1, 2, 4, 5 and 8 arrived at the accident scene approximately 11 minutes after the start of fire.

1.16 Tests and Research

In order to establish the accuracy of witness statements, a varying series of missed approaches were flown by a heavy jet aircraft. During this sequence, the witnesses consistently identified a particular type of approach and missed approach as similar to the one they had seen performed by RJ 600. This correlation supported statements by surviving crew members and the information later derived from the FDR.

1.17 Additional Information

The ALIA Flight Operations Manual contains comprehensive guidance material concerning wind shear and thunderstorm activity and the following extracts are quoted as relevant to this accident:

Wind Shear

"Wind shear is best described as an abrupt change in wind direction and/or velocity in a very short distance in the atmosphere. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground. For example, wind direction changes of 180° and velocity changes of 50 kt or more within 200 ft of the ground have been observed. However, this is not something that is encountered every day; in fact, the unusualness of the wind shear phenomenon makes it all the more a problem.

"The most common cause of significant low-level wind shear is the gust front associated with a thunderstorm. Although this front may be as much as 10 miles ahead of the thunderstorm, a clue to the flight crew that wind shear may be present is the thunderstorm itself.

"The worst possible occurrence in a shear is to fly into a sudden tailwind with its attendant loss of lift and airspeed. Downwind landings, certain noise abatement climbout headings, and similar manoeuvres can put an airplane in this situation when shear is present.

"The probability of encountering wind shear during the approach should be assessed as described previously. The Captain should, however, supplement this information with a comparison of the latest wind directions and velocities at various stations in the vicinity of the destination.

"In the terminal area and during the approach, moreover, the Captain should monitor the INS winds and compare them with the surface winds for a low-level wind shear indication. When the wind from the INS is not available during the approach, the difference of INS ground speed and the TAS should be compared with the surface headwind or tailwind component as a measure of shear. The Captain should: (1) brief the flight crew on possible shear conditions,

(2) check if runway length permits use of reduced landing flap setting, (3) add an increment of speed to the normal approach speed, (4) back up the autothrottles manually or use manual thrust control, and (5) instruct the crew to monitor thrust, pitch attitude, vertical speed, IAS, and turbulence.

"During the approach the required thrust and vertical speed are the most important and easily recognized parameters associated with the wind shear phenomenon.

"The most hazardous consequences occur when a wind shear occurs close to the ground after thrust adjustments have been already made during the approach to compensate for wind".

Thunderstorm activity

"In the mature stage, the mass of water, snow and hail increases to the extent that it can no longer be supported by the drafts. The resulting precipitation causes downdrafts which can be very strong and turbulent.

"The dissipating stage occurs after the downdrafts and precipitation have spread and the updrafts have disappeared. Turbulence is much less intense than in the preceding stages. Every thunderstorm has one or more separate cells of updrafts and downdrafts with turbulence of varying intensity. The thunderstorm cloud represents only the visible portion of the updraft and downdraft areas. Turbulence from these drafts also exists outside the cloud area.

"The greatest turbulence is associated with the areas of heaviest rain concentrations. Severe turbulence is usually encountered between altitudes of 12 000 and 20 000 ft but may be found at any level. Moderate to severe turbulence can also be evident up to 10 000 ft above the cloud tops when high wind conditions exist.

"The strong winds and low-level wind shears that precede thunderstorms are known as 'gust fronts' or 'plow winds'. Gust fronts can be extremely hazardous during the flight phases associated with takeoff and landing. Typical gust front structure and characteristics are:

A. A surface wind shift often accompanies the gust front but may lead the front by up to 5 miles.

B. Ground-level sustained winds and gusts to 50 kt are common; occasionally, winds approach 100 kt.

C. The gust front moves faster than the thunderstorm from which it was created and may lead the thunderstorm radar echo by 5 to 10 miles.

D. Airplane or ground radars may show the gust front as a thin line echo caused by differences between the high air density behind the front and the relatively low air density ahead of it.

E. The gust front may travel faster at approximately 2 500 ft above ground level than on the surface; therefore, it should be expected even further ahead of the thunderstorm than surface disturbances may indicate.

F. Vertical wind shears of 10 kt/100 ft extending from the surface to several hundred feet above the ground may occur.

G. Horizontal wind shears of 50 kt per mile have been measured while crossing perpendicularly through the gust front, and the shear may be even greater in thunderstorm squalls. [See "Wind Shear", this chapter.]

H. The pressure jump reported in hourly weather sequence reports is helpful in determining the position of the gust front. The pressure jump usually precedes the gust front by approximately three miles.

I. A pressure altitude increase of 200 to 300 ft is common in advance of the gust front."

2. ANALYSIS

2.1 Aircraft Operations

No evidence of aircraft mechanical failure came to light during the investigation, and the First Officer and the Flight Engineer confirm that the aircraft handled and performed normally throughout the flight.

The Captain had recently completed a course of training in the process of qualifying for command of the Boeing 727 and could be expected to have had extensive recent practice in "go around" techniques. In addition, all the available evidence, including FDR & CVR readouts, indicates that the crew correctly followed Flight Manual "go around" procedures and maintained the appropriate aircraft attitude, speed and configuration from initiation of the last missed approach to impact with the ground.

In consequence of the above, it is considered that neither mechanical failure nor mishandling by the flight crew caused the aircraft to descend to the ground.

However, the meteorological data indicates that there was severe thunderstorm activity at and in the vicinity of the airfield when the accident occurred, and it is concluded that the aircraft was forced to the ground by a downburst associated with the thunderstorm activity, the effects of which exceeded the climb capability of the aircraft by a catastrophic margin. The decision by the flight crew to continue the approach to land in known thunderstorm conditions had a direct bearing on the accident and this point is therefore considered.

The forecast of a 30 per cent probability of thunderstorms in the Doha area was made available to the flight crew before take-off from Amman.

At first contact with the aircraft, Doha ATC passed on the current METAR and advised of thunderstorm activity at and near the airfield. During the approaches to RWs 16 and 34, ATC passed reports of heavy rain and frequent wind changes to the aircraft. These reports, plus evident lightning and turbulence and a 3 mb pressure change in 30 minutes, should have alerted the flight crew regarding the thunderstorm activity.

Thorough and comprehensive briefing material regarding thunderstorms and wind shear is contained in the ALIA Flight Operations Manual. There is no indication that the many warnings and cautions in the Manual were taken into account when the approach to RW 34 was commenced.

However, based on the available evidence it is considered that the flight crew did not wilfully enter into an area of severe weather conditions, but rather failed to understand the significance of the warning signs which should have alerted them to the severity of the weather system and the possible consequences of attempting the approach.

The First Officer flew the aircraft throughout the flight and the possibility that this factor may have contributed to the accident was considered. The Captain held Company authorization to permit the First Officer to fly the aircraft during take-off and landing. Limitations on such authorization include:

a) the runway must be clean and dry;

b) the crosswind component shall not exceed 15 kt;

c) for any landing or take-off the maximum tailwind allowable shall be 10 kt.

If the First Officer had landed the aircraft off the last approach, limitations a) and c) would have been exceeded. However, a landing was not made and no technical infringment occurred. In addition, the CVR transcript shows that the Captain maintained a close monitoring function throughout the approach and was contemplating a missed approach during the descent on the ILS. Although the runway conditions were unsuitable for landings by a First Officer, there is no evidence to suggest aircraft mishandling by the flight crew and it is concluded that the fact that the First Officer was at the controls of the aircraft was not a contributory factor to the accident.

2.2 Fire Service Operations

Because the Duty Fire Officer did not receive positive instructions to the contrary he remained, together with his fire vehicle group, at the "bad weather standby" position for RW 34 until he was called to the accident site by the crew of Rescue 6. This call was made some eight minutes after the fire started and resulted in the main strength of the Fire Service arriving at the scene of the accident some eleven minutes after impact.

The division of responsibility between ATC and Watchroom regarding the co-ordination of Fire Service action when vehicles were deployed at "bad weather standby" positions was not defined in the orders for the Watchroom attendant and for the controller.

From a statement made by the controller, it is apparent that he believed that, not long after he had operated the crash alarm, a fully informed Watchroom had assumed responsibility for controlling the Fire Service and that he was free to follow post-crash procedures as laid down in his instructions. On the other hand, the Watchroom attendant, who had not been trained to regard it as his task to redeploy Fire Service vehicles once they were upon the airfield, took no further action after calling "Fire, fire, fire, Watchroom, fire".

The basic reason for the delay in summoning the main strength of the airfield Fire Service therefore occurred because of the controller's assumption that the Watchroom attendant was exercising control over fire vehicles when this was not in fact the case. The delay was extended because of the communications problem between the Watchroom and the Duty Fire Officer, and by the use of non-standard R/T procedures.

3. CONCLUSIONS

3.1 The crew were properly licensed and qualified to conduct the flight.

3.2 The aircraft was properly certificated and had been correctly maintained.

3.3 The aircraft was being operated within its prescribed limitations.

3.4 There was no pre-crash failure of the aircraft or its systems.

3.5 The ALIA Flight Operations Manual provides specific guidance related to thunderstorm and wind shear encounters.

3.6 The flight crew did not take proper account of the Flight Operations Manual guidance relative to thunderstorm and wind shear encounters.

3.7 The aircraft was forced to the ground in a downburst the effects of which exceeded the climb performance of the aircraft.

3.8 The Airport Fire Service was manned and equipped to International Civil Aviation Organization Category 7 and was adequate for B-727 operations.

3.9 The main strength of the airfield Fire Service did not arrive at the scene of the accident until approximately eleven minutes after the fire had started.

3.10 Cause

The cause of the accident was the aircraft's encounter with a downburst associated with a thunderstorm, the effects of which exceeded the performance capability of the aircraft. The encounter resulted from the flight crew's decision to conduct an approach to land without due regard to the prevailing weather conditions.

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